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Droplets behavior of subcooled dispersed phase under nucleate boiling of continuous phase of liquid emulsion

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ABSTRACT

The paper considers the influence of the dispersed phase of the emulsion upon the nature of heat and mass transfer in systems of immiscible liquids. In particular, is studied the interfacial interaction and breakage of subcooled drops of the dispersed phase during bubble boiling of the continuous phase of the emulsion. They predetermine the complex nature of the joint behavior of hydrodynamic and thermal processes. It is known that the controlled conditions for dispersion of emulsions in MQCL method under the minimum amount of cooling lubrication be able to improve the quality of metal processing by 10–18% (Maruda et al., 2017). Phase changes liquid generate in it a special kind of pulsation motion: «hot» turbulence of the superheated continuous phase. She is generated by process formation of nuclei and growth of steam bubbles accompanying by the pressure pulsations. Thus heat energy is converted into mechanical energy of the perturbed by the movement of vapor bubbles in evaporating liquid. The formula for the evaluating perturbations of the continuous phase of the emulsion under the influence of vapor bubbles is proposed. The behavior of these fluctuations depends on the frequency of the viable vapor phase nuclei formation related to the heat flow density. The dependence, obtained by Labuntsov (2000) for boiling homogeneous liquid, is used as a characteristic of the thermal velocity.

Taking into account the character of the boiling of the continuous phase of emulsion, the generalization of the Kolmogorov-Hinze model has been performed for breakage drops in isothermal flow of emulsion under the influence of turbulent fluctuations of velocity. A correlation model of "thermal" breakup is proposed, which is complementary to the physical representations of the breakup for subcooled drops during the liquid emulsion boiling. Using dimensionless criteria was justified the form of the correlation for the maximum stable droplet size and thermal velocity fluctuations. This makes it possible to relate mechanisms hydrodynamic and thermal processes at use of usual computer tools used in practice for engineering calculations. The correlation for the maximum stable droplet size and thermal velocity fluctuations was developed in a dimensionless form. The results of the model studies were evaluated using the experimental data on the breakup of drops of oil in coolant "oil-water" (Januszkiewicz et al., 2004). They were obtained under conditions of creeping flow in a narrow channel, eliminating the creation of ordinary hydrodynamic turbulence. A good agreement with experimental data indicates that the present model would be promising for the extension of model representations about the breakup of droplets in complex processes of heat and mass transfer in liquid emulsions.

1. Introduction

Emulsion immiscible liquids define efficiency and product quality in a wide variety of industries. They are widely used in chemical processes technology, in methods of metal processing, in manufacture of pharmaceutical and food products [1–4]. Particulate processes (also known as dispersed-phase processes) are characterized by the co-presence of strong interaction between a continuous media and a particulate (dispersed) phase and are essential in making many high-value industrial products [5]. New technologies with using emulsions of immiscible fluids and pose new challenges to the engineering profession including the heat transfer problems [6]. The desired end technological effect is achieved by constructing special units for each of them and by the creation of conditions conducive to interfacial interaction and to obtain the desired result [7] (see Fig. 1).

To successfully apply emulsions of immiscible liquids in various areas of industry, it is necessary to predict favorable hydrodynamic

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